Office of Power Technologies
Distributed Generation Overview

Turbine Power Systems Conference

Galveston
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Stephen Waslo
Chicago Operations Office
U.S. Department of Energy




Introduction

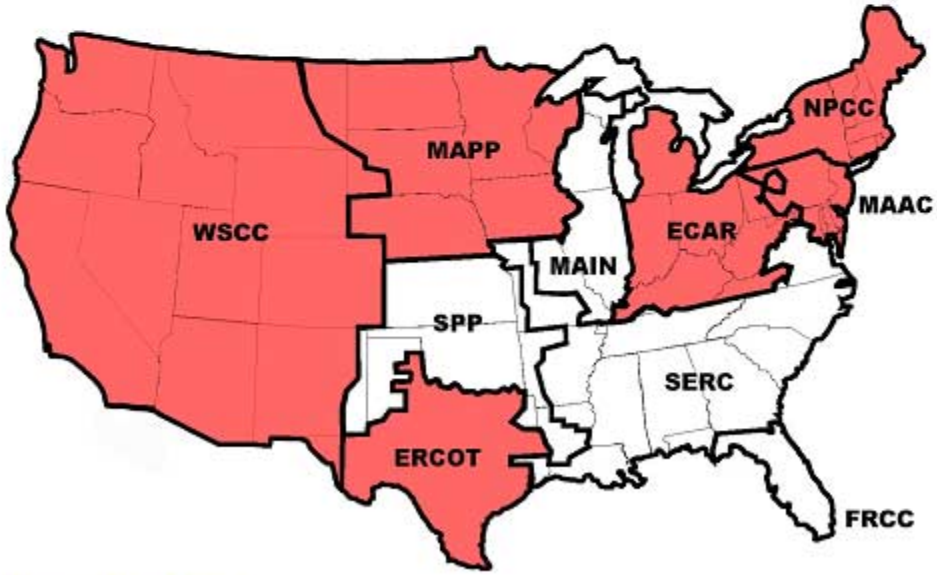
The Problem

Power Reliability Concerns

"If the energy infrastructure of this country is inadequate or in some way excessively costly, it will undermine economic growth, and is therefore a major issue that must be addressed."
Alan Greenspan, *January 26, 2001*

2009 Projections

Areas with Capacity Margins < 10 percent



Source: National Electricity Reliability Council, 2000

Solving the Growing Oil Gap

Renewables, Efficiency and Natural Gas Can Help

"To meet our energy challenge, we must put to good use the resources around us and the talents within us."
Vice President Dick Cheney

Hydrogen Energy

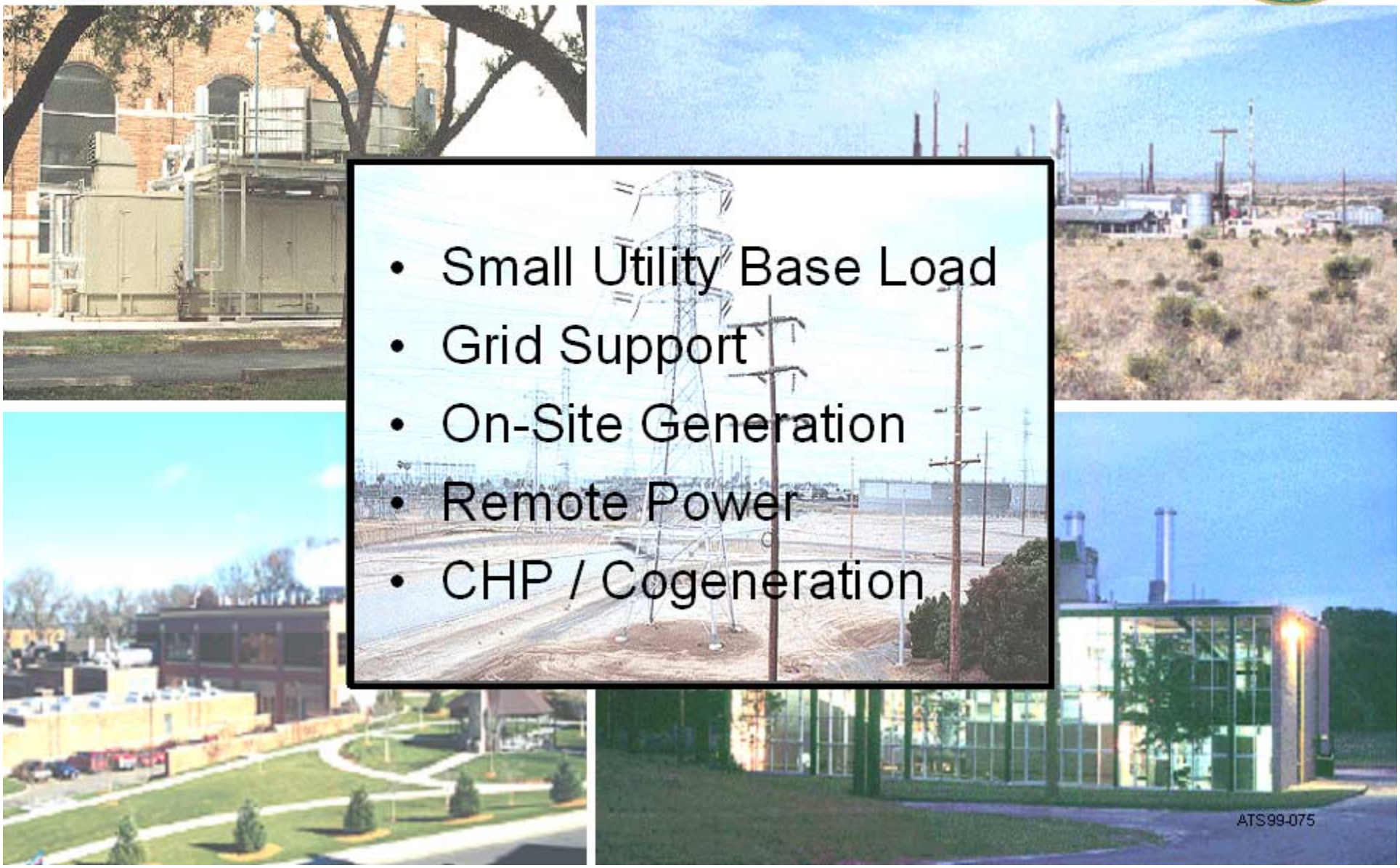
Biofuels, Power, and Products

Natural Gas – Distributed Power

Distributed Energy Recources

A Key Solution

Distributed Energy Resources



DER "Prime Movers"

Examples

Advanced Turbines

Reciprocating Engines

Photovoltaics

Fuel Cells

Wind

Microturbines

Office of Power Technologies

Renewable Energy

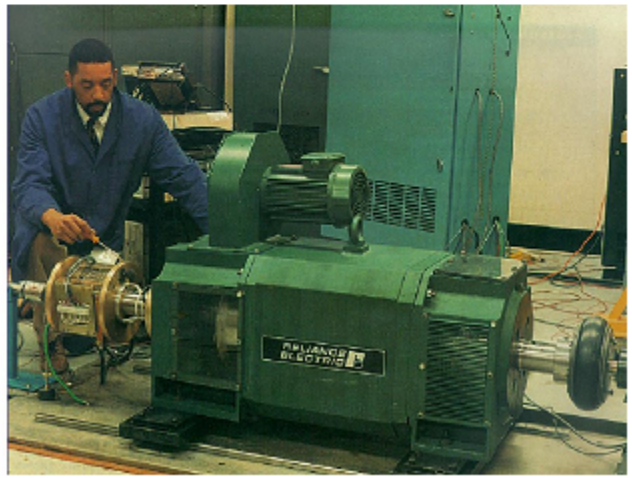
- Biopower
- Solar Technologies
- Wind
- Geothermal
- Hydrogen
- Hydropower

Distributed Energy Resources

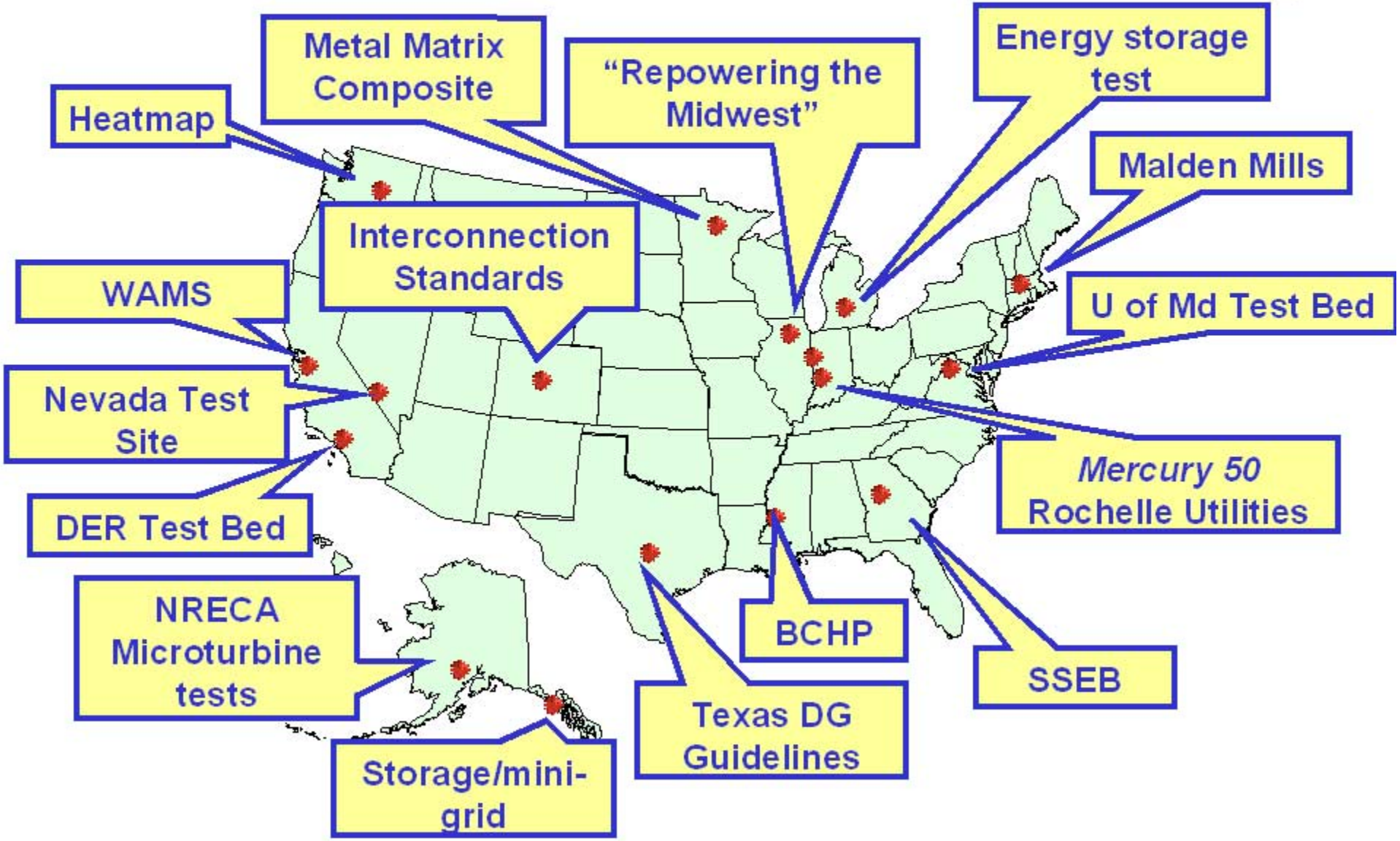
- Natural Gas turbines, fuel cells & engines
- Interconnection Standards
- Thermally Activated Technologies
- Natural Gas-Renewable Hybrids

Reliability/ Power Quality

- Power Delivery
- Superconductivity
- Transmission Reliability
- Energy Storage
- Smart Controls



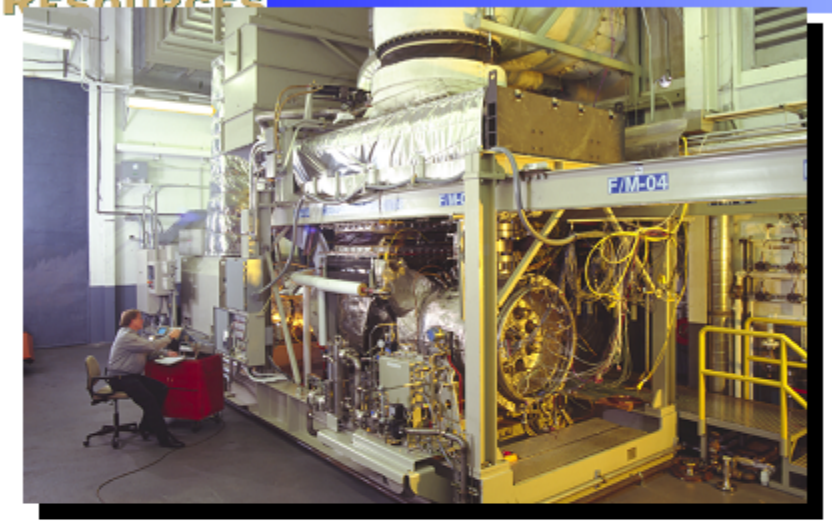
DER Strategic Activities



ATS

The Current Baseline

Mercury 50 Demo Sites



Development Test Cell

Load Management at Factory

Peaking Duty at Remote Mine

Municipal Utility Economic Dispatch

CMC Gas Turbine Combustor Liners

- Texaco - Bakersfield, CA
  - >19,900 Hours of Field Operation
  - High Time: >13,937 Hours on One Liner Set
    - Liners: H-ACI SiC/SiC (CVI/MI)
    - UTC EBC
- Malden Mills - Lawrence, MA
  - >9,500 Hours of Field Operation
    - Liners: H-ACI/BFG SiC/SiC (CVI/MI)
    - UTC EBC
- Reduced Emissions
  - <15 ppm NOx, < 10 ppm CO

RAMD Test at Silicon Valley Power

- Reliability, Availability, Maintainability, Durability
- Run 8000 hours on the grid
- Three Kawasaki M1A-13X Turbines to be installed in Northeast
- Candidate for GE 10 in California

Through 7400 hours:
NOx < 2.5 ppm
CO < 6 ppm
UHC < 6 ppm

Advanced HPT Vane

- Current Costs $45,000 per engine per year or $0.0013 per Kw-hr
- Operational cost savings are being verified by field test evaluation
- Advanced material HPT vanes currently installed at two end user sites accruing durability time

Gas Turbine Technology Drivers

Seeking Solutions for Industrial Gas Turbine

- Emissions standards more restrictive
- Horizons of new technologies
- Critical advances in materials systems
- New targets
  - **< 5 ppm NOx**
  - **Consideration for transition to back-up fuels**
  - **Durable for at least 8000 hours**
  - **No more than 10% cost add-on**
  - **No negative impacts on gas turbine performance**

Advanced Materials

- Higher firing temperatures
- Reduced component cooling

→ Improved thermal efficiency
Increased output power

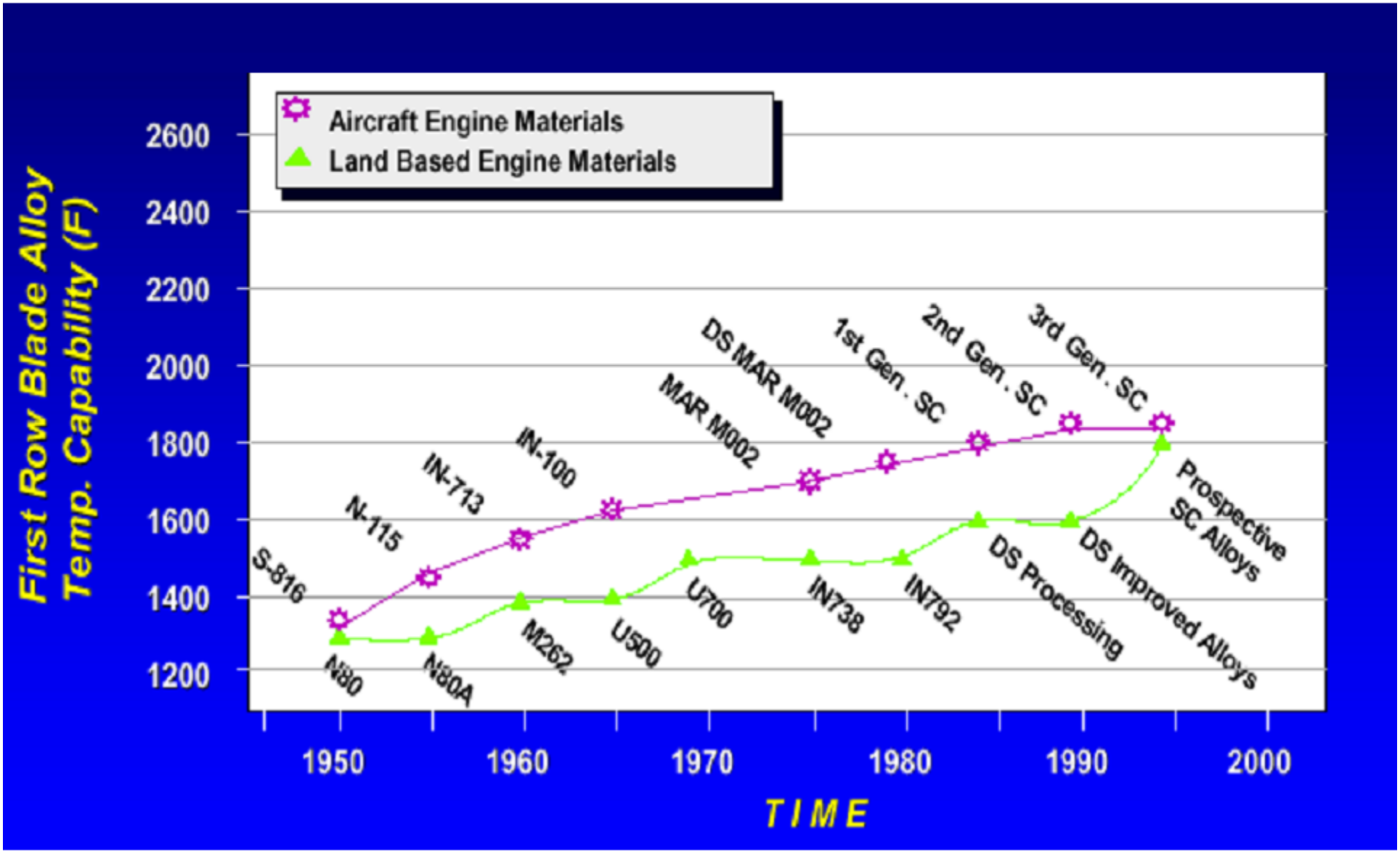
- Reduced emissions of NOx and CO

→ Energy Savings
Environmental Benefits

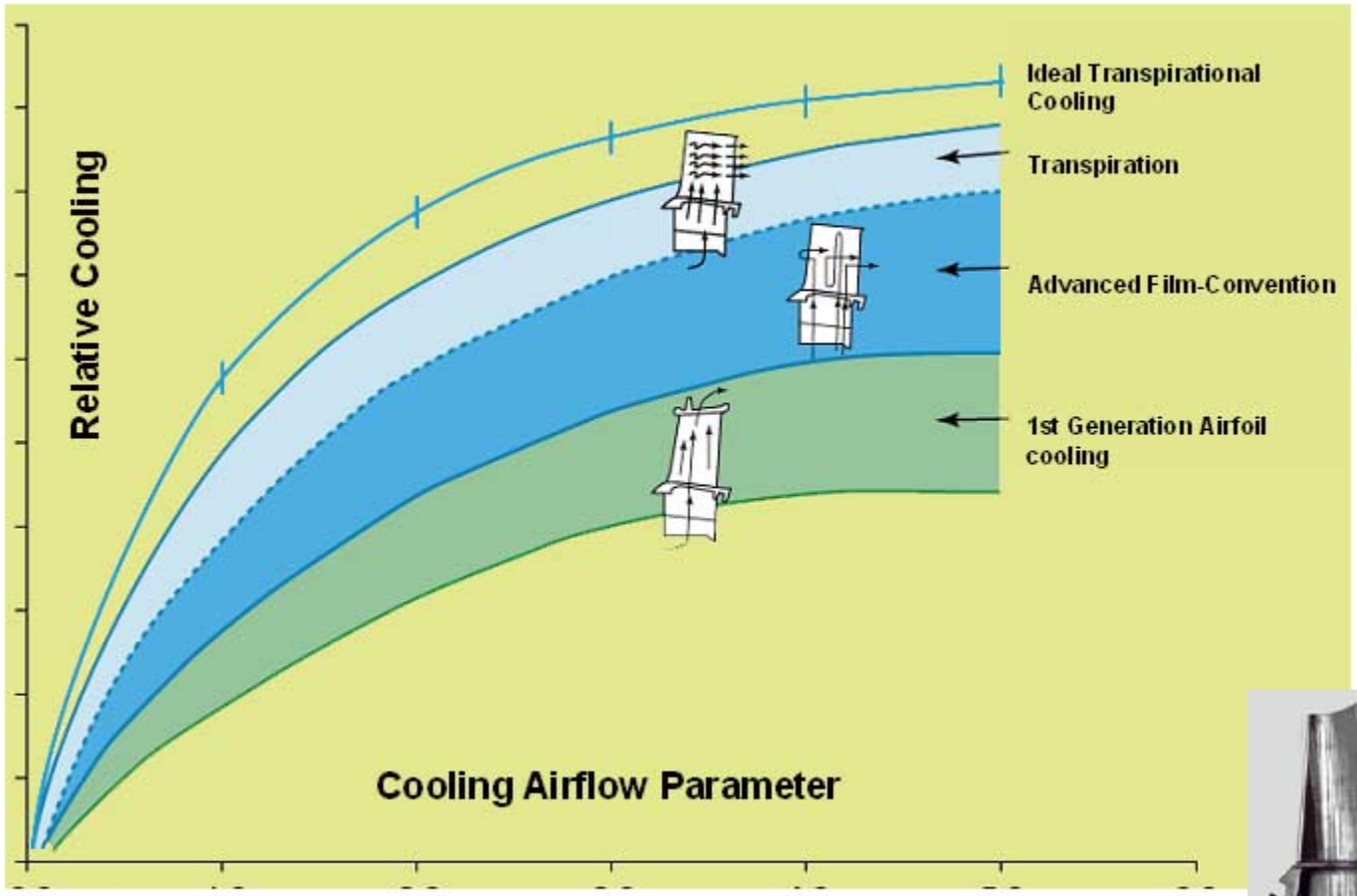
- Improve component durability
  - 30,000+ hrs required
    - turbine blades, nozzles
  - Simplify component designs

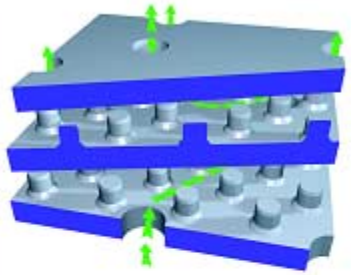
→ Lower Component Cost

History of Engine Materials



Airfoil Casting

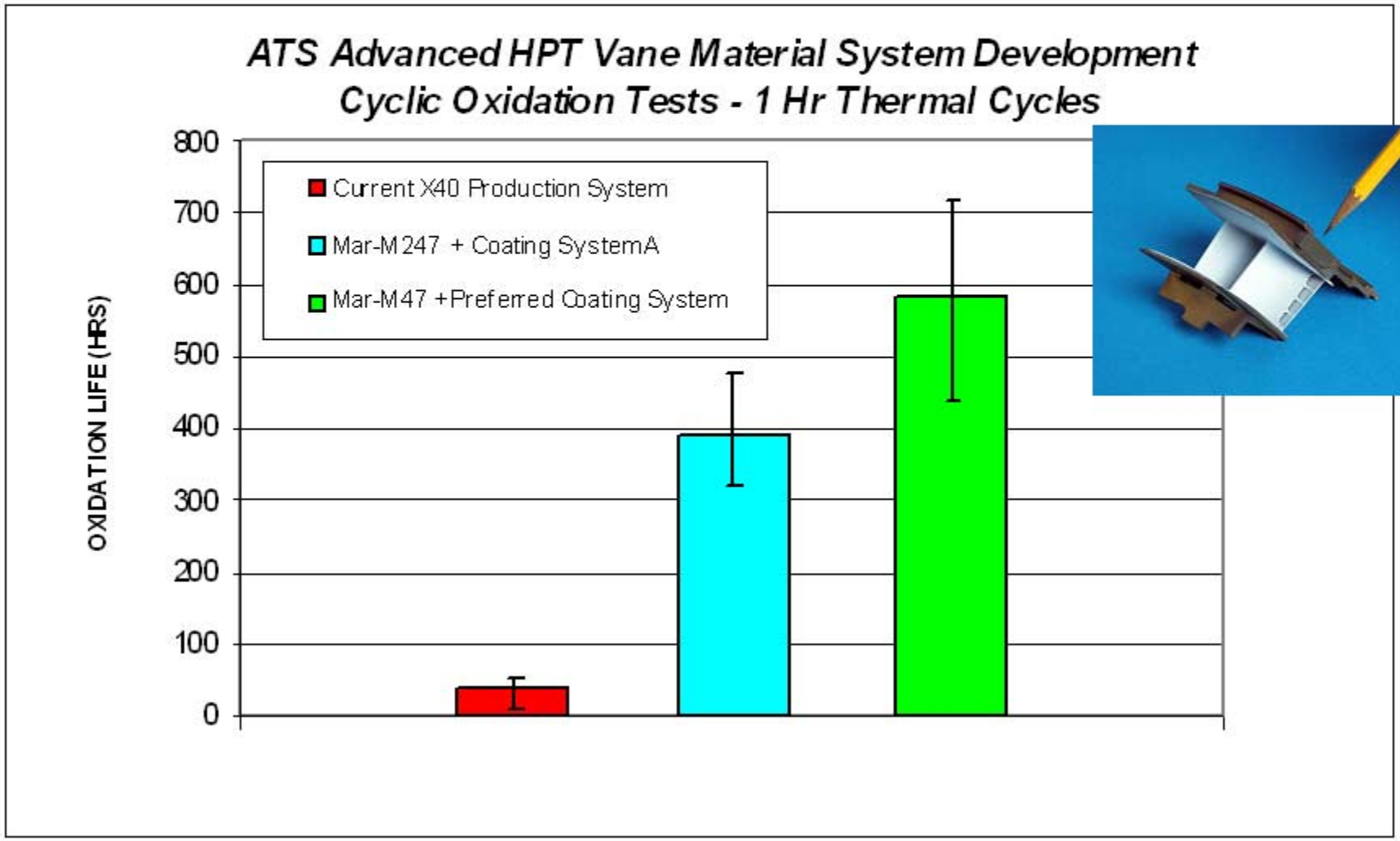




Core Materials

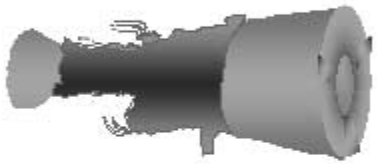
SX Casting

Prime Reliant Thermal Barrier Coatings (TBC)



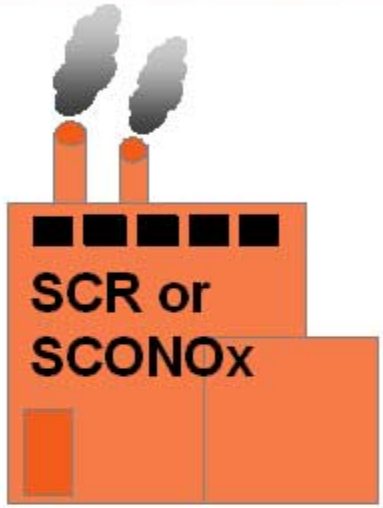
Low Emissions Perspective on the Options

Conventional Turbine



\+ Water injection
Steam injection
Lean premix

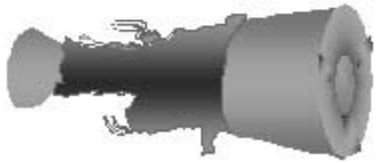
\+



Cleanup

→ Less than >3 ppm

Catalytic Combustor Turbine



→ Less than 2.5 ppm

DER Advanced Turbine Program

Advanced Turbine Program Goals

- Development of environmental and performance solutions for gas turbines that broaden opportunities for meeting the nation's energy demand with efficient, affordable, and reliable power.

- To reach this goal, bring together relevant stakeholders in strategic partnerships to develop, test, and commercialize optimized and fully integrated low-emission technologies and advanced materials.

Contractors

Advanced Materials

- GE Corporate Research & Development
- Teledyne Continental Motors
- Siemens Westinghouse
- Solar Turbines

Low Emissions

- Alzeta
- Catalytica
- Honeywell Engines and Systems
- Precision Combustion
- Solar Turbines

DOE Funding is $14.0 Million over 3 years

Advanced TBC for W501F Siemens- Westinghouse

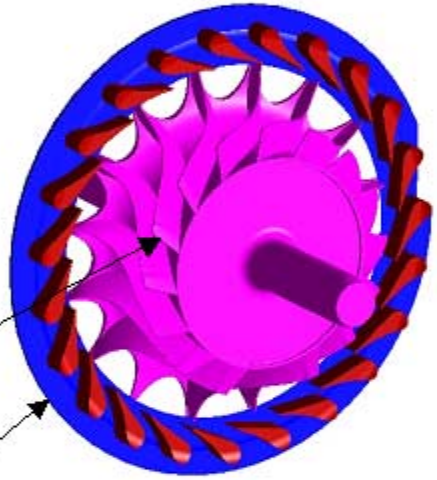
- Vanes and blades successfully coated
- Improved sintering resistance
- High resistance to thermal cycling
- 20% reduction in thermal conductivity
- Engine tests to demonstrate extended maintenance interval and lower COE

SIEMENS
Westinghouse

Teledyne Advanced Materials for Microturbines

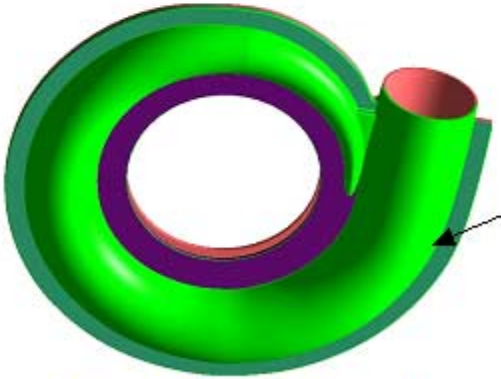
- **Improve efficiency 120%**
- **50% reduction in cost of rotor**
- **Significant cost reduction for other parts**

Turbine Inlet Nozzle and Rotor



Low Cost Powdered Nickel Superalloy

High Temperature Titanium Silicon Carbide (Ti_3SiC_2)



Turbine Scroll

CONTINENTAL MOTORS
A Teledyne Technologies Company

GE's Path for CMCs in Gas Turbines

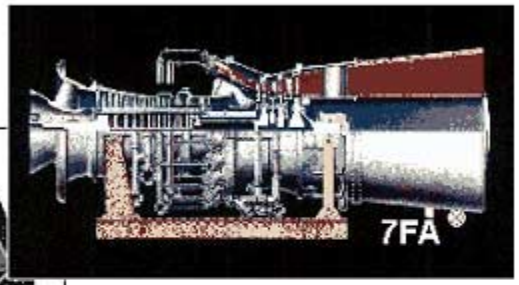
Stg. 2 Shroud

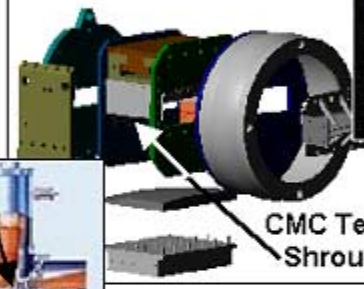
Stg. 1 Shroud

MI-CFCC

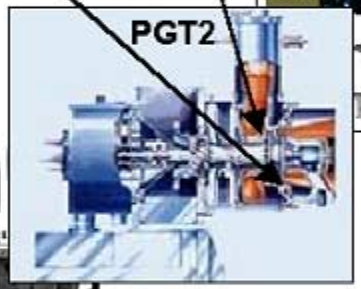
HS-188

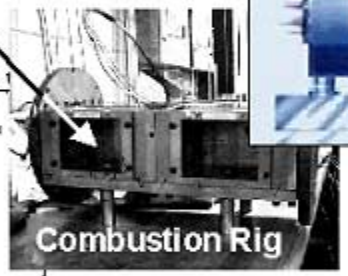
New Combustion Rig

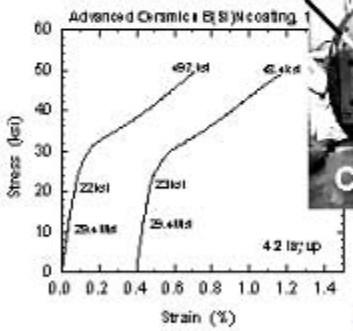




CMC Test Shroud







Large Engine Validation Test

4000 -8000 hrs at Field Site

Rig Qualification Tests

50+ cycles & 300 total hours

Small Engine Testing

60 cycles & 1000+ hrs

Rig Feasibility Tests

200+ cycles & 200 hrs

Lab Tests

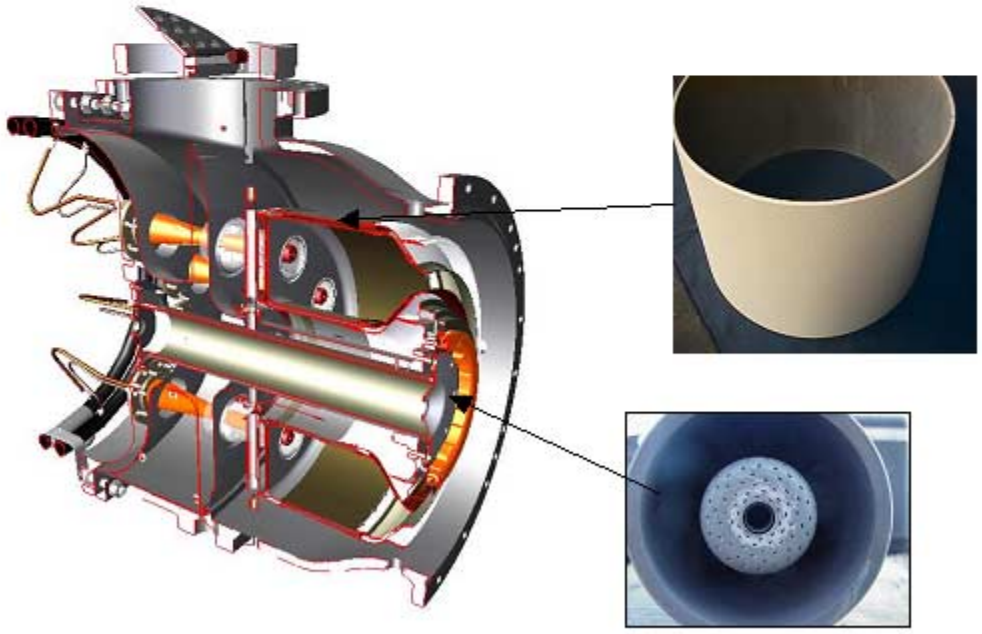
DoE CFCC Pgm.

DoE AMAIGT Pgm.

Progressive testing provides risk reducing "stepping stones" to engine test

Advanced Materials
Solar Turbines Mercury 50

Focuses on improving durability of combustor liners using advanced TBCs, ODS alloys, and CFCCs, and fuel injectors using ODS and monolithic silicon nitride



Solar® Turbines
A Caterpillar Company

Catalytica Combustion System

- Improve performance of Catalyst
- Solve system design problems
- Select optimal materials
- Lower maintenance costs
- Ready for commercial turbine

Alzeta Surface Stabilized Combustion

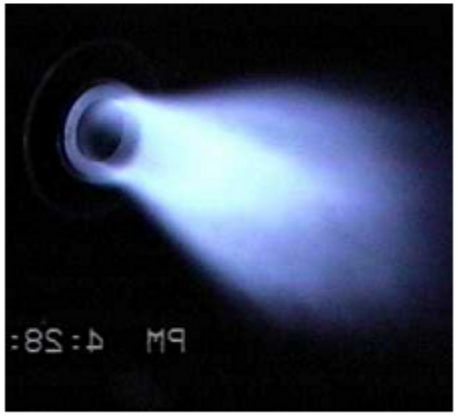
- **Uniform axial flow**
- **Cast monolithic**
- **No weld seams**
- **Selectively perforated**
- **NOx < 3 ppm**

T60 Injector

Precision Combustion RCL

- **No preburner**: Compressor discharge
- **Robust**: No flashback / auto-ignition
  Tolerates fuel/air transients
- **Durable**: Well-moderated temperatures
- **Compact**: Available space, low Δp
- **Premixing**: Relaxed requirements
- **Simple**: Air and fuel control
- **Multi-Fuel**: Natural gas, bio-based gas,
  and pre-vaporized liquids

Full < 3ppm NOx



Pilot < 5ppm NOx

PCI
Precision Combustion, Inc.

Status of Catalytic Combustion

Completion of low emission technologies is critical to the Nation's energy security

- Catalytica
  - Three Kawasaki M1A-13X Turbines to be installed for Distributed Generation in the Northeast U.S.
  - Agreement of sale of six GE PGT 10 gas turbines to Alliance Power
- PCI
  - Competitive catalytic technology option enjoys high interest of several OEMs
- Alzeta
  - High potential for economic solution including uncontrolled markets

Summary

- Gas turbines will continue to play an important role in the Energy future of the United States by providing clean, reliable, and environmentally-friendly power for the new millennium
- Gas Turbines will be a strong competitive option for distributed power
- Materials technology is a key enabler for advances in gas turbines
- Continued government/industry collaborations will leverage our resources and advance technologies